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Research Paper

Response of aerobic rice (*Oryza sativa*) to different irrigation regimes and nitrogen levels in western Odisha

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ABSTRACT

A field experiment was conducted during the summer seasons of 2013 and 2014 at Chiplima, Odisha, to determine the effect of irrigation regimes and nitrogen (N) levels on yield, field water-use efficiency (FWUE) and economics of 'APO' cv. of aerobic rice (*Oryza sativa* L.). The treatments consisted of 4 irrigation regimes (irrigation at 3, 5, 7 and 9 days intervals) in the main-plots and 4 levels of nitrogen (0, 40, 60 and 80 kg N/ha) in the sub-plots, replicated thrice. The pooled mean results revealed that maximum grain yield (3.44 t/ha) and benefit: cost ratio (1.40) were obtained when irrigation was provided at 3-day interval. However, the both the parameters obtained with irrigation being provided at 5-day interval were at par with their maximum values. The field water-use efficiency was the maximum with irrigation at 7-day interval (36.01 kg/ha-cm) which was at par with irrigation at 5-day interval (34.48 kg/ha-cm). With regards to N level, application of 80kg N/ha recorded significantly higher grain yield (3.58 t/ha), FWUE (40.55 kg/ha-cm) and benefit: cost ratio (1.48) than that of other N levels. Thus, economically higher grain yield, FWUE and benefit: cost ratio were obtained when crop was irrigated at 5-day interval and fertilized with 80 kg N/ha.

Key words: Aerobic rice, Economics, Field water use efficiency, Irrigation regimes, Nitrogen

Rice production is a key to world food security and India needs to produce 1.7 million tonnes of additional rice in each year to maintain national food security (Dass and Chandra, 2013). Rice plays a pivotal role not only in our national food security but also provides livelihood to millions of rural households. Rice productivity is under threat, as its production in Asia, which constitutes three-fourths of total rice production of the world, is increasingly constrained by water limitations. It is forecast that by 2025 over 17 million ha and 22 million ha of Asia's irrigated rice area may experience physical water scarcity and economic water scarcity respectively (Toung and Bouman, 2003). The declining rate of per capita freshwater availability necessitates production of rice with limited water, using alternate management options, which can increase the water-use efficiency (WUE) and reduce its losses. The traditional rice production system not only leads to wastage of water but also causes environmental degradation and above all reduces the fertilizer-use efficiency. Rice consumes heavy quantum of irrigation water and thus, requires 3,000–5,000 litres water to produce 1 kg rice, depending on the variety and rice cultivation methods (IRRI, 2001). Aerobic rice culture is an emerging technology and revolutionary way of growing rice where the direct-seeded rice varieties with aerobic environment are grown in well-drained, un-puddled and non-saturated soils (aerobic soils) in order to increase the WUE. Aerobic rice assumes greater importance in water-scarcity area and increasing demand for rice

Nitrogenous fertilizer is the major and most limiting nutrients for growth and development as well as yield of rice in almost all environments (Shrestha and Maskey, 2005). In lowland rice ecosystems, the nitrogen-use efficiency (NUE) is approximately 30%, whereas in upland rice whether irrigated or rainfed, NUE would be in the range of 40 to 60%. As aerobic rice culture is a new system, there is need to quantify the requirement of N for

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aerobic rice with particular reference to cultivars location and management conditions. Odisha is having substantial area under rainfed/semi-dry rice and has a vast scope of growing rice under aerobic conditions. Since, reliable information on vital agro-techniques for successful aerobic rice culture in this region is absolutely lacking, present study was taken to see the effect of aerobic rice to varied irrigation regimes in conjunction with levels N for achieving maximum production as well as WUE.

MATERIALS AND METHODS

An experiment was conducted at the Regional Research Technology and Transfer Station, Chiplima, Sambalpur, Odisha, India during the summer seasons 2013 and 2014. The study area comes under the West Central Table Land Zone of Odisha and is situated at (latitude, longitude and altitude of 20°212 N, 80°552 E and 178.8 m above mean sea-level) respectively. Soil of the experimental field was sandy loam with acidic in reaction (*p*H 5.8), with organic carbon content of 0.38%, and available N, P and K contents187, 15.4 and 172 kg/ha respectively. The moisture contents at field capacity and permanent wilting point were 19.4 and 8.4% respectively. The experiment was laid out in a splitplot design with 3 replications. Main plot treatments consisted of four irrigation regimes (irrigation at 3, 5, 7 and 9 day interval) in the main-plots and 4 levels of nitrogen (0, 40, 60 and 80 kg N/ha) in the subplots. Total 48 (16 × 3) plots of size 30 m^2 (6 m × 5 m) were used for the experiment. Seeds of 'Apo' cultivar was manually sown @ 45 kg/ha in furrows made by trench hoe at 20-cm-row spacing during the first week of January and harvested on the second week of May in both the study years. The recommended dose N, P_2O_5 and K_2O for the region are 80, 40, 40 kg/ha respectively. Urea, single super-phosphate and muriate of potash were applied as sources of N, P_2O_5 and K_2O respectively. Urea was top dressed as per treatment in 3 splits, i. e. half dose of N at 20 days after sowing (DAS) and remaining half dose of N was applied in 2 equal splits each at 40 and 60 DAS.

The required cultural practices and plant-protection measures were followed as per recommended package. Weeds were controlled by pre emergence herbicide pendimethalin 30 EC (stomp) @ 1.0 litre/ha at 2 DAS and post-emergence herbicide metasulfuron methyl + chlorimuron 20 WP (almix) @ 20 g/ha 20 DAS followed by weeding with cono weeder at 30 DAS and 1 hand-weeding at 40 DAS. The crop was harvested when 90% of the grains were golden yellow. The grains were threshed, cleaned and sun-dried to record the grain yield (t/ ha) on the net-plot basis.

Initially, after sowing, 5 irrigations of 3 cm depth were applied to all the plots irrespective of irrigation treatments for proper establishment of the plants till 20 DAS. Thereafter, irrigations were applied as per the treatments. Water 5 cm was applied during each irrigation. It may be noted that the depth of irrigation refers to the depth of water applied and not the depth of standing water on the plots. The rainfall during the crop-growth period of both the years was sporadic; the total rainfall received was 65.9 mm and 9.1 mm in 2013 and 2014 respectively. Hence the intermittent rainfalls were not taken into account for rescheduling of irrigation. However, the initial 5 common irrigations along with the rainfall (effective rainfall i.e. 50% of total rain fall) were taken into account for computation of crop-water requirement under different treatments. The total number irrigations were 22, 15, 11 and 9 in 3, 5, 7 and 9 days interval, respectively, excluding the common 5 irrigations provided for crop establishment.

The irrigation water was measured through 90^o V-notch weirs set up in the pucca channel of the experimental field. The rate of discharge was calculated as:

$$Q = 0.0138 \times H^{\frac{5}{2}} \qquad \ldots(1)$$

where Q is the rate of discharge (litre/s) and H is the head over the crest (cm).

The time of irrigation for every plot was computed by using given depth of irrigation, area of the plot and discharge rate. It was calculated by the following formula:

$$t = \frac{10 \times A \times D}{Q} \qquad \ldots(2)$$

where Q is the rate of discharge (litre/s), A is the area of the plot (m^2), D is the depth of irrigation (cm) and t is the time of irrigation (s).

Water requirement (WR) was calculated by adding effective rainfall during crop-growth period, amount of irrigation water applied and soil profile moisture contribution(0–15cm).

Soil profile moisture contribution was calculated as : formulae

$$\text{Soil profile moisture contribution} = \left[\sum_{i1}^{n} \frac{\text{Mbi} - \text{Mei}}{100}\right] \times \text{BDi} \times \text{Di}$$

where n, number of soil layers considered in the root zone depth D; Mb_i, soil moisture percentage at the start of the season (sowing) in the ith layer; Me_i, soil moisture percentage at the end of the season (harvesting) in the ith layer; BD_i, soil bulk density in the ith layer (g/cm^3); D_i, depth of the ith layer in the root zone depth (cm).

Field water-use efficiency (FWUE) was calculated by dividing grain yield (kg /ha) with the total amount of water required (cm). From the pooled data, economics was worked out on the basis of prevailing market price of the produce and inputs used in the experiment.

The pooled analyses of the recorded data for various parameters were carried out using the procedures described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes

Effect of irrigation regimes and nitrogen levels on yield-attributing parameters and grain yield of aerobic rice (pooled mean of 2 years) revealed that the yield-attributing parameters were the highest with irrigation at 3-day interval (Table 1). However, the values of these parameters with irrigation at 5-day interval were statistically at par with those of the former and significantly superior to all other higher irrigation intervals with regards to spikelets/panicle and 1,000 grain weight. However, for effective tillers/m^2 and filled grains/panicle, irrigation at 3-day interval was significantly better than the other irrigation intervals (Table 1). This could be due to increase in growth characters, seed setting rate and 1,000-grain weight with adequate moisture availability throughout the crop-growth period. These results confirm the findings of Shekara *et al*. (2010). Among the N levels, the values of yield attributes such as effective tillers/m^2, spikelets/panicle and filled grains/panicle increased significantly with each successive increase in the levels of N, i.e., 80 kg/ha. But 1,000-grain weight increased significantly with each successive increase in the level of N up to 60 kg/ha and thereafter, the increase was not significant. The increase in yield-attributing characters of aerobic rice with the increase in N application might be owing to higher availability of N to plants leading to its higher uptake and translocation from vegetative parts to reproductive parts resulting in increased yield attributes. Better performance under application of N at 80 kg/ha in respect to yield attributes of rice under aerobic culture confirms the findings of Uddin *et al.* (2013) and Pradhan *et al.* (2014).

Yield

Grain yield of rice increased significantly with the decrease in irrigation interval up to 5-day and further decrease in irrigation interval did not prove beneficial during both the years under study (Table 1). The pooled value of both years also showed the same trend. The highest grain yields of 3.35, 3.53 and 3.42 t/ha were obtained with irrigation regime at 3 days interval in the first year, second year and pooled mean respectively. The increase in grain yield owing to irrigation at 3-day interval over 5, 7 and 9-day intervals were 6.3,24.5 and 41.8% in the first year, 7.0, 21.5 and 38.8% in the second year and 6.1, 22.5 and 39.8% in pooled mean, respectively. The pooled mean straw yield showed that straw yield increased significantly with the decrease in irrigation interval up to 3 days (4.94 t /ha). The lowest grain yield was obtained with the decrease in irrigation frequency. This might be due to reduced growth of plants, more number of emerged weeds and also the water stress suffered by the plants during reproductive phase that hampered the supply of photosynthates resulting in poor yield attributes. The results confirm the findings of Maheswari *et al*. (2008) and Shekara *et al.* (2010).

Among the N levels, the grain yield of rice increased significantly with the increase in N levels during individual years and pooled mean of both years**.** Application of 80 kg N/ha recorded the highest grain yield of 3.48, 3.68 and 3.58 t/ha in the first year, second year and pooled mean, respectively. The increase in grain yield owing to N

Table 1. Effect of irrigation regimes and nitrogen levels on yield-attributing parameters and grain yield of aerobic rice (pooled mean)

Treatment	Effective panicles/m^2 at harvest	Spikelets/ panicle	Filled grains/ panicle	1,000-grain weight (g)	Straw yield (t/ha)	Grain yield (t/ha)		
						2013	2014	Pooled
Irrigation regimes								
3-day interval	315.4	89.4	82.8	20.6	4.94	3.35	3.53	3.44
5-day interval	291.9	86.0	78.0	20.2	4.55	3.14	3.28	3.21
7-day interval	239.3	81.7	64.2	19.5	3.98	2.53	2.77	2.65
9-day interval	210.2	76.5	53.7	18.8	3.17	1.95	2.16	2.06
SEm ±	5.6	1.4	1.0	0.2	0.08	0.09	0.12	0.07
CD (P=0.05)	17.2	4.2	3.3	0.7	0.25	0.31	0.40	0.23
Nitrogen levels (kg/ha)								
0	218.7	74.3	57.2	18.2	2.88	1.83	2.02	1.91
40	253.5	81.8	66.6	19.5	3.87	2.59	2.79	2.69
60	278.5	86.0	73.4	20.5	4.67	3.07	3.26	3.16
80	306.2	91.5	81.5	20.9	5.23	3.48	3.68	3.58
SEm ±	4.8	0.9	0.9	0.2	0.05	0.08	0.09	0.06
CD (P=0.05)	13.0	2.6	2.5	0.6	0.16	0.23	0.26	0.17

at 80 kg/ha over 60, 40 and 0 kg/ha was 11.8, 25.6 and 47.4% in the first year, 11.4, 24.2 and 45.1% in the second year and 11.7, 24.9 and 46.6% in pooled mean respectively. The pooled mean straw yield of rice increased significantly with the increase in N up to highest level, i.e. 80 kg/ha (5.23 t/ha). The probable reasons assigned for application of N at 80 kg/ha resulted significantly higher grain yield than all other lower levels due to enhanced stature of growth and yield attributes, forming larger sink size coupled with efficient translocation of photosynthates from source, which would have resulted in more number of filled grain thereby finally reduced by grain yields. This is in accordance with the findings of Uddin *et al.* (2013) and Pradhan *et al.* (2014).

The interaction between different irrigation regimes and N levels on grain yield was found to be significant in pooled value of both the years (Table 2). The interaction of irrigation at 3-day interval with application of N 80 kg/ha gave the highest grain yield which was at par with irrigation at 5-day interval with the crop receiving N 80 kg/ha and significantly superior to other interaction of irrigation regimes with nitrogen levels.

Table 2. Interaction effect of irrigation regimes and nitrogen levels on grain yield (t/ha) of aerobic rice (pooled mean)

Irrigation regimes	Nitrogen (kg/ ha)			
	0	40	60	80
3-day interval	2.30	3.35	3.72	4.39
5-day interval	2.03	2.94	3.64	4.23
7-day interval	1.78	2.50	3.04	3.27
9-day interval	1.58	1.96	2.24	2.44
	I	N	I within N	N within I
SEm±	0.07	0.06	0.12	0.08
CD (P=0.05)	0.23	0.17	0.36	0.24

Water requirement and field water-use efficiency

Water requirement (average of 2 years) of different irrigation intervals varied from 63.6 to 128.2 cm (Table 3). The highest water requirement was observed with irrigation at 3-day interval, whereas the lowest value with irrigation at 9-day interval among different irrigation intervals. During the first year, the highest mean FWUE was observed with treatment that received irrigation at 7-day interval, which was at par with irrigation at 5-day interval and significantly superior to that of the other irrigations at 3-and 9-day intervals. The lowest value was observed with irrigation at 3-day interval. Similar trend was observed in pooled value of both the years. But during the second year, the irrigation regimes at 7-day interval registered the highest mean FWUE, which was at par with irrigation regimes at 5-day and 9-day intervals and significantly superior to irrigation regimes at 3-day interval. The irrigation regimes at 3 days interval gave lower-water use efficiency, though grain yield was higher. This is due to consumption of more quantity of water. Shekara *et al.* (2010) reported similar findings. The water requirement for N-treated plot which was the mean values of different irrigation treatment reflects the almost the same value for all N-treated plots. The FWUE increased significantly with the increase in application of N up to the highest level, i.e. 80 kg/ha. Similar trend was observed in both the years and pooled mean

Table 3. Effect of irrigation regimes and nitrogen levels on water requirement (WR), field water-use efficiency (FWUE) and economics in aerobic rice (pooled mean)

Treatment	Irrigation applied (IA) (cm)	Effective rainfall (ER) (cm)	Soil moisture contribution (SMS) (cm)	WR(cm) IA+ER+SMS (Avg. of 2 years)	FWUE (kg grain/ ha-cm)	Gross returns (× 10³₹/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio
					Pooled mean			
Irrigation regimes								
3-day interval	125.0	3.75	-0.55	128.2	26.8	49.6	14.2	1.40
5-day interval	90.0	3.75	-0.44	93.3	34.5	46.3	11.7	1.34
7-day interval	70.0	3.75	-0.22	73.5	36.0	38.4	4.3	1.12
9-day interval	60.0	3.75	-0.10	63.6	32.3	29.9	-3.9	0.88
SEm±	-	-	-	-	0.8	1.0	1.0	0.03
CD (P=0.05)	-	-	-	-	2.6	3.1	3.1	0.09
Nitrogen levels (kg/ha)								
0	86.25	3.75	-0.39	89.6	22.2	27.9	-6.0	0.82
40	86.25	3.75	-0.32	89.7	30.6	38.8	4.3	1.12
60	86.25	3.75	-0.31	89.7	36.2	45.8	11.0	1.13
80	86.25	3.75	-0.29	89.7	40.5	51.8	16.8	1.48
SEm±	-	-	-	-	0.5	0.8	0.8	0.02
CD (P=0.05)	-	-	-	-	1.3	2.3	2.3	0.07

under study. The application of N at 80 kg/ha revealed the highest mean FWUE, whereas the lowest value with no-N application in the first year, second year and pooled mean. The increase in N levels resulting in higher FWUE might be owing to increase in grain yield with almost constant rate of applied water. Maheswari *et al.* (2008) reported similar findings.

The interaction of irrigation regime at 5-days interval with application of nitrogen at 80 kg/ha resulted in the highest field water-use efficiency (Table 4). It was at par with irrigation regime at 7-days interval with application of N 80 kg/ha and significantly superior to the other interaction between irrigation regimes with nitrogen levels.

Table 4. Interaction effect of irrigation regimes and nitrogen levels on field water-use efficiency

Irrigation regimes	Field water use efficiency (kg/ha-cm)			
	Pooled			
	Nitrogen levels (kg/ha)			
	0	40	60	80
3-day interval	17.9	26.0	29.0	34.1
5-day interval	21.7	31.5	39.0	45.2
7-day interval	24.2	34.0	41.3	44.4
9-day interval	24.8	30.8	35.2	38.3
SEm±		1.16		
CD (P=0.05)		3.29		

Economics

Among the irrigation treatments, pooled value of both years indicated that maximum gross returns, net returns and benefit: cost ratio in aerobic rice were obtained from the crop irrigated at 3-day interval which was at par with irrigation at 5-day interval and significantly superior to the other irrigation regimes (Table 3). Irrigation regimes at 3-day interval recorded higher gross returns, net returns and benefit: cost ratio, which might be owing to higher grain yield with higher irrigation levels. Similar findings obtained by Shekara *et al.* (2010). Pooled value of both years showed that the maximum gross returns, net returns and benefit: cost ratio in aerobic rice was obtained from the crop receiving N at 80 kg/ha. It was significantly superior to that of the other N levels. Higher gross returns, net returns and benefit: cost ratio were recorded with application of N at 80 kg/ha might be owing to higher grain yield with higher N levels. Reddy *et al.* (2012) and Pradhan *et al.* (2014) reported similar findings.

It was concluded that crop receiving irrigation at 5-day interval along with application of N at 80 kg/ha can produce economically higher grain yield (4.23 t/ha) and FWUE (45.26 kg/ha-cm) under aerobic culture in rainfed and water-scarce west central table land zone of Odisha.

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